



**National Renewable Energy Laboratory**  
*Innovation for Our Energy Future*

# SAM Wind Analysis



**Webinar**

**Tom Ferguson**

**June 2011**



- Introduction to SAM
- Modeling a wind farm
- Running SAM, Viewing Results
- Advanced Topics
- Demonstration



SAM Wind Analysis

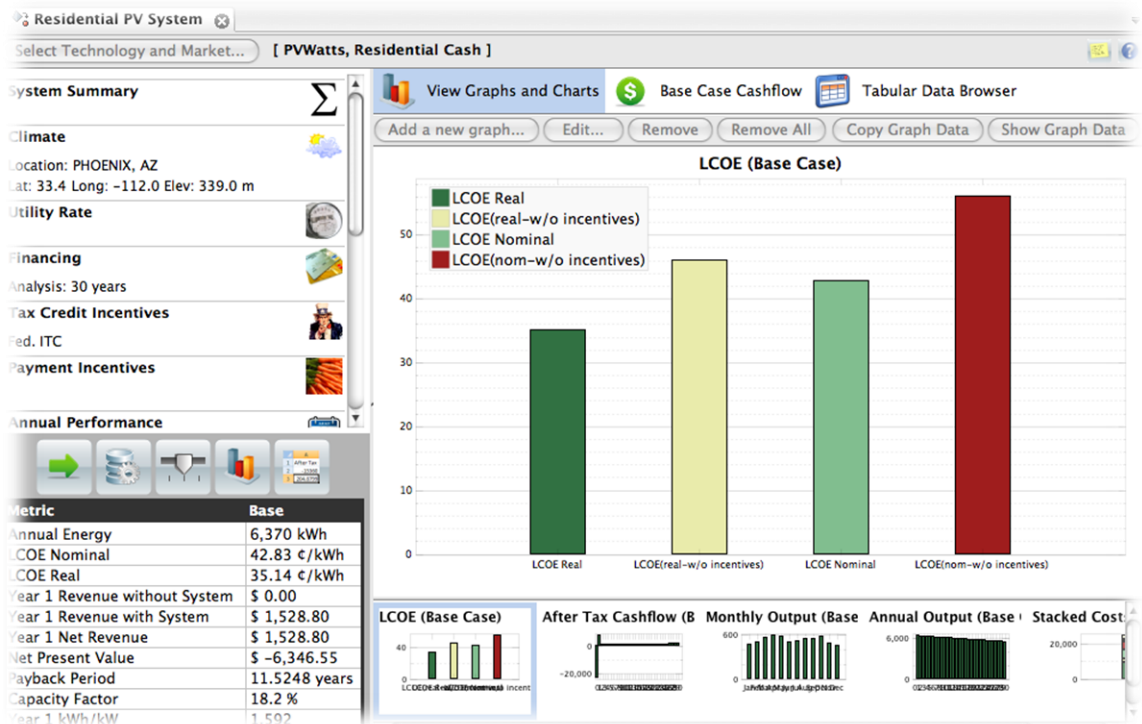
# INTRODUCTION TO SAM

# What is SAM?



The System Advisor Model (SAM) is a free computer program that **calculates a renewable energy system's hourly energy output** over a single year, and **calculates the cost of energy** for a renewable energy project over the life of the project.

These calculations are done using detailed performance models, a detailed cash flow finance model, and a library of reasonable default values for each technology and target market.



# What can you do with SAM?



- Model solar, wind, and geothermal power systems in a single application
- Access high-quality performance and economic models developed by NREL, Sandia, and other partners
- Evaluate and compare options using consistent models across technologies
- Calculate economic metrics such as LCOE, NPV, payback for projects in different markets
- Perform parametric and uncertainty analyses
- Present modeling results in graphs and tables



- Photovoltaics
- Concentrating Solar Power
  - Parabolic Troughs
  - Power Towers
  - Dish-Stirling
- Solar Water Heating
- Wind turbines and farms
- Geothermal power plants

## Key outputs

- Hourly energy production (kWh)
- Capacity factor

- Residential, commercial, and utility-scale projects
- Installation and operating costs
- Tax credit and payment incentives
- Complex electric utility rates

## Key outputs

- Levelized Cost of Electricity (LCOE)
- Payback
- Net present value
- Multi-year cash flow

# Background



Developed by the Department of Energy, National Renewable Energy Laboratory, and Sandia National Laboratories

## Vision

- Model different renewable energy projects in a single platform
- Facilitate technology comparison by handling performance, costs and financing consistently across technologies
- Make high-quality performance models developed by NREL, Sandia, and other partners available to the public

# Users and Applications



## Feasibility studies

- Project developers, Federal Energy Management Program

## Use as benchmark for other models

- System integrators and utilities

## Research projects

- Universities and engineering firms

## Plant acceptance testing for parabolic trough systems

## Evaluate technology research opportunities and grant proposals

- Department of Energy

**35,000+ Downloads**

Manufacturers  
Engineering Firms  
Consultants  
Developers  
Venture Capitalists  
Policy Analysts



# Current Development Team



## Management

- Nate Blair, NREL

## Programming

- Aron Dobos, NREL
- Steven Janzou, NREL\*
- Tom Ferguson, NREL\*

## PV Model Validation

- Chris Cameron, Sandia

## Photovoltaics

- Bolko von Roedern, NREL

## Concentrating Solar Power

- Mark Mehos, NREL
- Craig Turchi, NREL

## Water Heating

- Jay Burch, NREL
- Craig Christensen, NREL

## Geothermal

- Chad Augustine, NREL

## Documentation and User Support

- Paul Gilman, NREL\*

\* Contractors

# Wind Modeling capabilities in SAM



SAM has three models related to wind: Small Scale Wind, Utility Scale Wind, and Wind Turbine Design

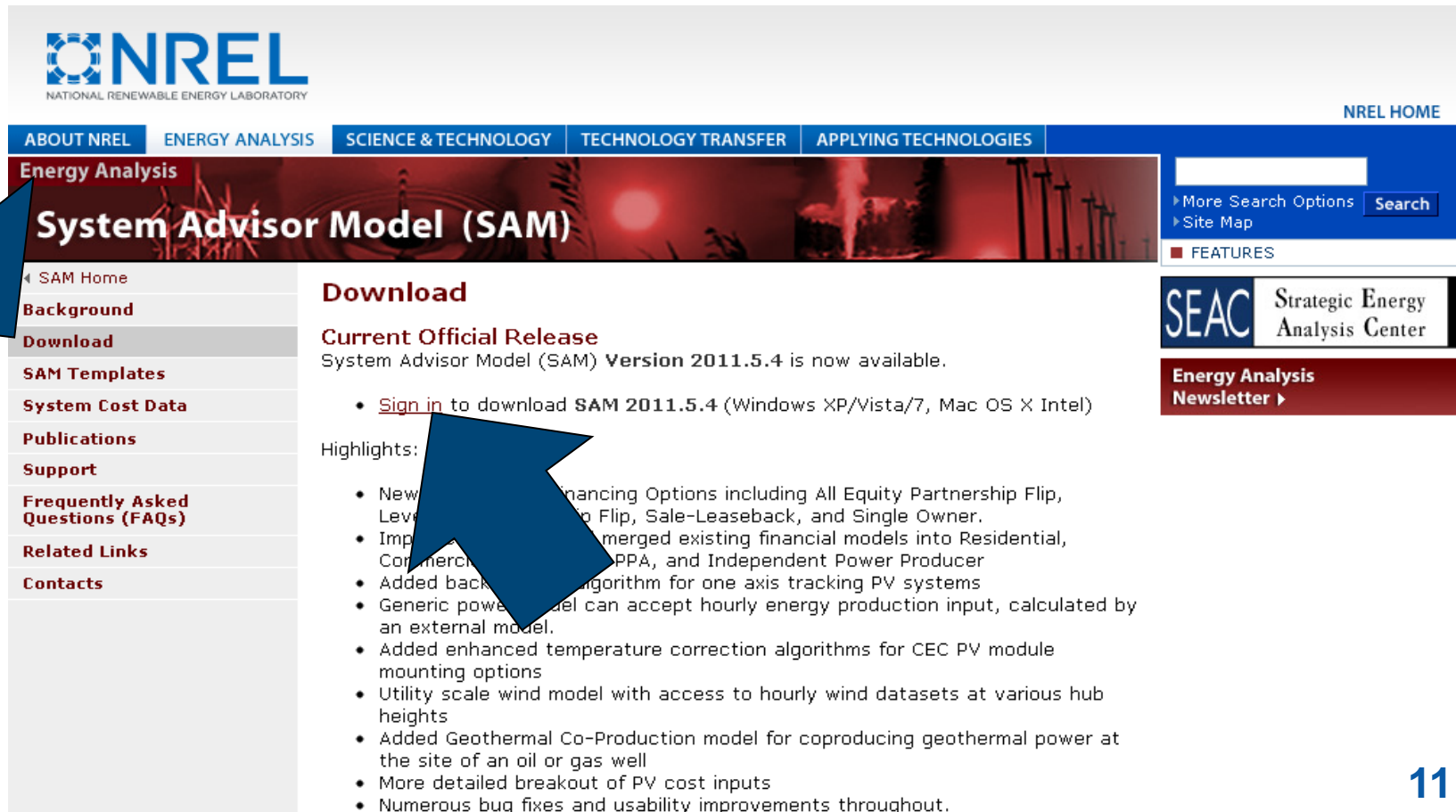
- Small scale and Utility scale wind models
  - Hourly simulation for one year (8760 hours)
  - Require a wind resource data file with wind speed and direction
  - Can model more than one turbine including simple wake effects based on an algorithm developed by Pat Quinlan
- Wind turbine design model
  - Focuses on turbine design (component costs vs. efficiency)
  - Uses link to external spreadsheet to calculate costs
  - No hourly simulation: it uses a Weibull distribution to calculate a likely annual output
  - Single turbine only

# Downloading SAM



<http://www.nrel.gov/analysis/sam>

1) Sign in 2) Complete registration form 3) Download



The screenshot shows the NREL SAM website. A large blue arrow on the left points to the 'Download' link in the left-hand navigation menu. Another large blue arrow on the right points to the 'Sign in' link in the 'Current Official Release' section. The website header includes the NREL logo and navigation tabs for 'ABOUT NREL', 'ENERGY ANALYSIS', 'SCIENCE & TECHNOLOGY', 'TECHNOLOGY TRANSFER', and 'APPLYING TECHNOLOGIES'. The main content area is titled 'System Advisor Model (SAM)' and features a 'Download' section with the 'Current Official Release' of SAM 2011.5.4. A search bar and 'More Search Options' link are visible in the top right corner.

**NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

**ENERGY ANALYSIS**

**System Advisor Model (SAM)**

**Download**

**Current Official Release**  
System Advisor Model (SAM) **Version 2011.5.4** is now available.

- [Sign in](#) to download **SAM 2011.5.4** (Windows XP/Vista/7, Mac OS X Intel)

Highlights:

- New financing Options including All Equity Partnership Flip, Lease-to-Own Flip, Sale-Leaseback, and Single Owner.
- Improved financial models merged existing financial models into Residential, Commercial, PPA, and Independent Power Producer
- Added backtracking algorithm for one axis tracking PV systems
- Generic power model can accept hourly energy production input, calculated by an external model.
- Added enhanced temperature correction algorithms for CEC PV module mounting options
- Utility scale wind model with access to hourly wind datasets at various hub heights
- Added Geothermal Co-Production model for coproducing geothermal power at the site of an oil or gas well
- More detailed breakout of PV cost inputs
- Numerous bug fixes and usability improvements throughout.

**SEAC** Strategic Energy Analysis Center

**Energy Analysis Newsletter**

# Getting Help



## Online Help and User Guide

- Help menu and buttons



## SAM Website

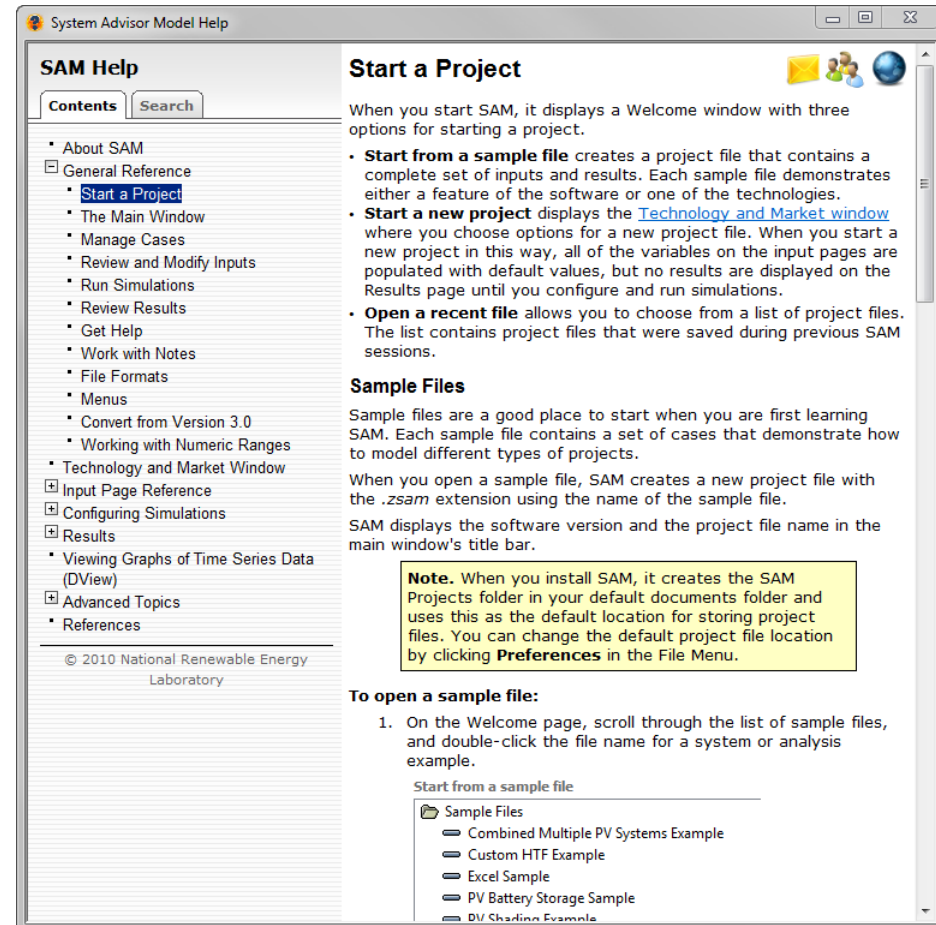
- <http://www.nrel.gov/analysis/sam>

## Google Groups

- <http://groups.google.com/group/sam-user-group>

## Email User Support

- [solar.advisor.support@nrel.gov](mailto:solar.advisor.support@nrel.gov)





SAM Wind Analysis

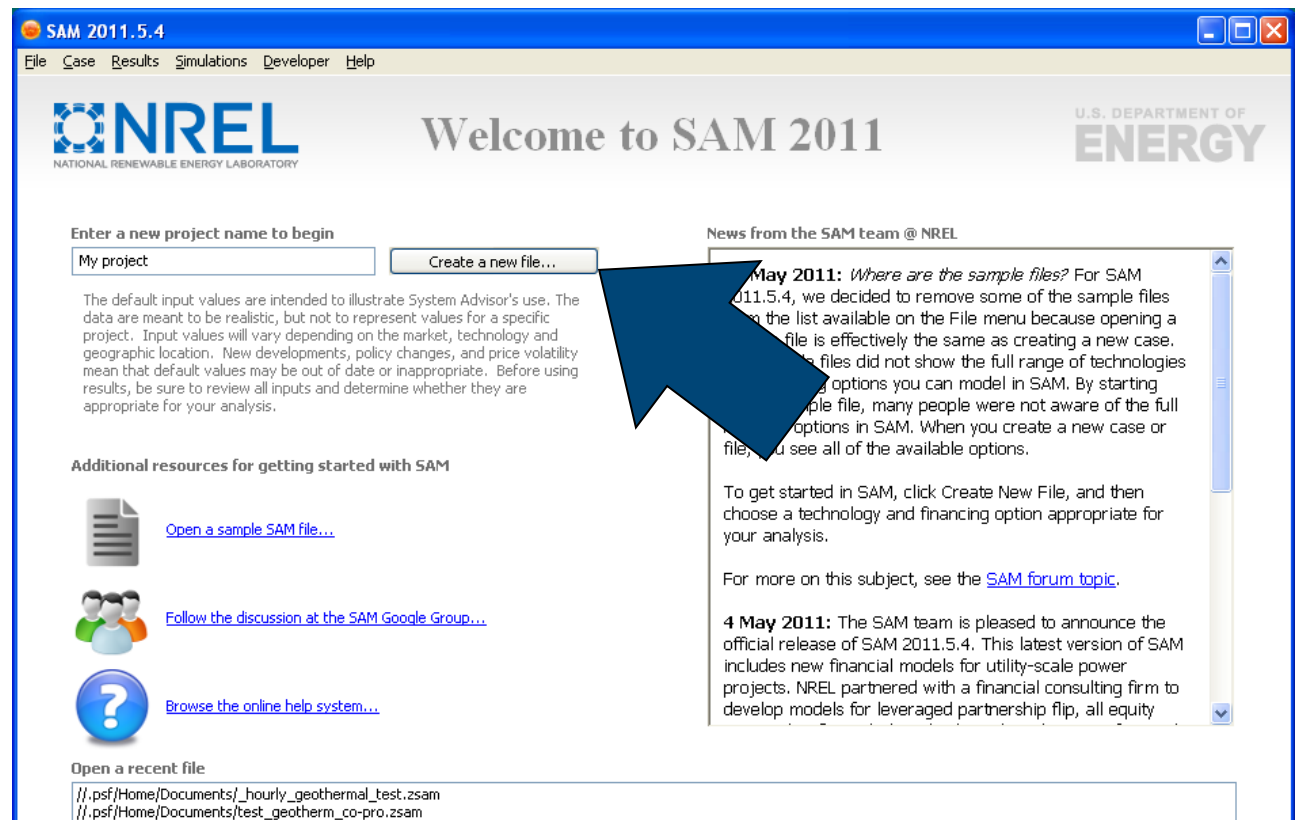
# MODELING A WIND FARM

# Initial Screen



## SAM's current startup screen

- Click the “Create a new file...” button to create a case and choose the technology option and financing option



# Choosing to model wind



- 1) Click on “Wind”
- 2) Select the “Utility Scale Wind” sub-category.
  - With the technology sub-category selected, the appropriate financing categories will appear.
- 3) Click on “Utility Market”
- 4) Select IPP.

**1. Select a technology:**

- Photovoltaics**  
Direct conversion of sunlight to electricity using solar cells.
- Concentrating Solar Power**  
CSP systems use mirrors or lenses to concentrate a large area of sunlight into a small area to generate a heat source for conventional type power cycles.
- Generic System**  
The simplest plant model that uses a nameplate size and factor or user supplied production profile.
- Solar Water Heating**  
Conversion of sunlight to thermal energy for producing domestic hot water.
- Wind**  
Wind systems capture energy from blowing wind to turn the blades of a windmill or turbine.
  - Small Scale Wind**  
An hourly wind model meant to simulate a few small (< 100 kW) turbines providing power to a home or business.
  - Utility Scale Wind**  
An hourly model meant to simulate a full scale wind farm with large turbines (>500 kW, over 50 meters tall) providing power to the electricity grid.
- Geothermal**  
Geothermal systems extract heat energy from the relatively large heat content of the earth for conventional power cycles.
- Biomass Power**  
Conversion of biomass feedstocks into electricity.

**2. Select a financing option:**

- Utility Market**  
Financial models appropriate for utility scale power projects.
- Independent Power Producer**  
This option is the same as the Utility IPP financing options in older versions of SAM. A power generation project developed and owned by a single entity that sells electricity at a price negotiated through a power purchase agreement (PPA). You specify a target IRR, with optional constraints on the minimum DSCR, positive cash flow, debt fraction, etc. SAM calculates the project PPA price, IRR, and NPV. This option is a simplified version of the Single Owner option.
- Advanced**  
Advanced financial models appropriate for utility scale power projects.
- No Financials**  
Only system performance outputs are available since no financial analysis is performed.

Buttons: Help..., Ok, Cancel

# Inputs - General



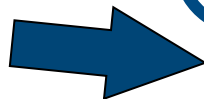
The case you created becomes a tab.



Select different input pages by clicking an item in this list



Run the model



The screenshot shows the SAM 2011.5.4 software interface. The title bar reads 'SAM 2011.5.4: untitled1'. The menu bar includes 'File', 'Case', 'Results', 'Simulations', 'Developer', and 'Help'. A tab labeled 'My project' is active. Below the tab, a button says 'Select Technology and Market...' and the project name is '[ Utility Scale Wind, Independent Power Producer ]'. The left sidebar contains a list of input categories: 'System Summary' (selected), 'Financing', 'Tax Credit Incentives', 'Payment Incentives', 'Annual Performance', 'Wind Resource', 'Wind Farm Specifications', 'Wind Farm Costs', 'Energy Payment Dispatch', and 'User Variables'. Each category has a small icon. The main area displays the 'System Summary' page with the following data:

System Summary	
Nameplate Capacity	64000 kW
Total Direct Cost	124,588,800.00 \$
Total Installed Cost	124,588,800.00 \$
Total Installed Cost per Capacity	1,946.70 \$/kW
Analysis Period	30 years
Inflation Rate	2.5 %
Real Discount Rate	5.5 %

At the bottom, there is a toolbar with icons for 'Run' (green arrow), 'Data' (cylinder), 'Model' (gear), 'Results' (bar chart), and 'Help' (question mark).

Input pages specific to wind





# Wind model input requirements



Hourly weather data for one year

Wind farm capacity

- Selecting a turbine from the wind turbine library, or adding a turbine to the library (to add a turbine, you will need the turbine power curve)
- Wind farm layout

System costs: Installation and operating costs

Financial assumptions

- Loan parameters for all projects
- Target IRR for utility projects
- Incentives and tax credits

# Inputs – Wind Resource



SAM wind requires resource data that covers 8760 hours (1 year)  
For western states, SAM can lookup the wind resource data online

Use the  
“**Location Lookup...**”  
button to retrieve  
resource data for a  
particular location.

**SAM 2011.5.4: untitled1**

File Case Results Simulations Developer Help

My project x [ Utility Scale Wind, Independent Power Producer ]

Select Technology and Market...

**System Summary**

**Financing**

Analysis: 30 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 1 % per year  
Availability: 100 %

**Wind Resource**

Lat: 41.2 Long: -104.8 Elev: 1868.1 m  
Distance from request: 3.9

**Wind Farm Specifications**

Turbine: V90-2.0  
System Size: 64000.0 kW  
Hub Height: 90 m

**Wind Farm Costs**

**Energy Payment Dispatch**

**User Variables**

**Choose Wind Resource Location**

Wind Data File: SAM/cheyenne wy\_2005.swrf

Data source: <http://scctest/wsis/wwwis?lat=41.14&lon=-104.82&year=2005>

Date created: 2010-10-14 05:42:21

Latitude Requested: 41.14 deg

Longitude Requested: -104.82 deg

Latitude: 41.175 deg

Longitude: -104.825 deg

Distance from request: 3.9 km

Elevation: 1868.07 m

Location Lookup...

Add/Remove...

Refresh list

Copy to project

Remove from project

SAM looks for weather files in the specified folders. To change the search folders, click "Add/Remove". The prefix "SAM/" indicates a location from the standard SAM library, and those preceded by "USER/" are stored in your project file to facilitate sharing with other people.

[Click here to view map of \(R\)equested and \(A\)ctual locations](#)

**Annual Average Data**

Wind speeds at different heights

Height (m)	Wind Speed (m/s)
10 meters	3.93137
20 meters	5.22065
50 meters	6.57106
100 meters	7.66317

The green checkmark indicates the appropriate data for turbine hub height. If no checkmark is visible, the hub height is not appropriate for this wind data. SAM will use the marked data with the appropriate shear factor

Temperature at 10m: 8.49854 °C

View hourly data...

**Wind Resource Details**

Shear Coefficient: 0.14

Turbulence Coefficient: 0.1

# Inputs – Wind Farm Specifications



Choose a wind turbine from a library of over 70 turbines

The screenshot displays the SAM 2011.5.4 software interface for a wind farm project. The left sidebar contains a 'System Summary' section with various tabs: Financing, Tax Credit Incentives, Payment Incentives, Annual Performance, Wind Resource, Wind Farm Specifications, Wind Farm Costs, Energy Payment Dispatch, and User Variables. The 'Wind Farm Specifications' tab is selected, showing a list of turbines with 'V90-2.0' highlighted. A large blue arrow points from the text 'Choose a wind turbine from a library of over 70 turbines' to the 'V90-2.0' selection. Another blue arrow points from the same text to the 'Wind Turbine' section of the main panel.

**Wind Turbine**

Model Name: SAM/Large Scale Wind Turbine Library/V90-2.0

V90-2.0: 2000.0 kW, rotor 90.0 m

Nameplate Capacity: 2000 kW  
Rotor Diameter: 90 m  
IEC Class: IIIa  
Cut-in Wind Speed: 4 m/s  
Hub Height: 90 m  
Closest available resource ht: 100 m

Turbine Output (kW) vs Wind Speed (m/s) graph showing a power curve that starts at 4 m/s, rises to a peak of 2000 kW at 15 m/s, and then drops to zero at 25 m/s.

**System Size**

☒ Use more than one wind turbine

Number of Turbines: 32  
System Nameplate Capacity: 64000 kW

**Turbine Farm Layout**

Shape: Square / Rectangle / Parallelogram

Turbines per Row: 8  
Number of Rows: 4  
Turbines in Layout: 32  
Turbine Spacing: 500 m  
Row Spacing: 750 m  
Offset for Rows: 250 m  
Offset Type: Each Row  
Row Orientation: 0 deg

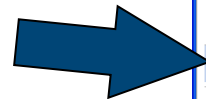
Wind Farm Losses: 0 %  
Losses per turbine: 0 kW

Turbine Layout Map showing a grid of 32 turbines arranged in 4 rows and 8 columns, with a compass rose indicating North (N), South (S), East (E), and West (W).

# Inputs – Wind Farm Costs



Two basic cost categories: installation and O&M



SAM 2011.5.4: untitled1

File Case Results Simulations Developer Help

My project x

Select Technology and Market... [ Utility Scale Wind, Independent Power Producer ]

**System Summary**

**Financing**

Analysis: 30 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 1 % per year  
Availability: 100 %

**Wind Resource**

Lat: 41.2 Long: -104.8 Elev: 1868.1 m  
Distance from request: 3.9

**Wind Farm Specifications**

Turbine: V90-2.0  
System Size: 64000.0 kW  
Hub Height: 90 m

**Wind Farm Costs**

**Energy Payment Dispatch**

**User Variables**

**Direct Capital Costs**

	Per Unit	By Capacity	Fixed	Cost Totals
Cost of all Turbines				\$ 115,200,000.00
Installation	5000 \$/turbine	0 \$/kW	0 \$	\$ 160,000.00
Balance of System	0 \$/turbine	0 \$/kW	0 \$	\$ 0.00

**Single Turbine Cost**

Fixed Cost per Turbine	0 \$
Cost by capacity	1800 \$/kW
Single Turbine Cost	\$ 3,600,000.00

Contingency: 8 % \$ 9,228,800.00

Note: Contingency applies to the sum of the total turbine, installation, and balance of system costs.

Total Direct Cost \$ 124,588,800.00

**Indirect Capital Costs**

	% of Direct Cost	Non-fixed Cost	Fixed Cost	Total
Engineer, Procure, Construct	0 %	\$ 0.00	\$ 0.00	\$ 0.00
Project, Land, Miscellaneous	0 %	\$ 0.00	\$ 0.00	\$ 0.00
Sales Tax of	0 % applies to	100 % of Direct Cost		\$ 0.00

Total Indirect Cost \$ 0.00

**Total Installed Costs**

Total Installed Cost \$ 124,588,800.00

Total Installed Cost per Capacity (\$/kW) \$ 1,946.70

**Operation and Maintenance Costs**

	First Year Cost	Escalation Rate (above inflation)
Fixed Annual Cost	0.00 \$/yr	0 %
Fixed Cost by Capacity	50.00 \$/kW-yr	0 %
Variable Cost by Generation	0.00 \$/MWh	0 %
Fossil Fuel Cost	0.00 \$/MMBTU	0 %

Notes

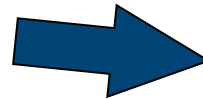
1) Escalation rates do not apply to O&M annual schedules, only first year values.

2) Fossil fuel cost is not applicable to PV or Dish Stirling systems. Set to zero for these systems.

# Inputs – Financial Assumptions



Financial inputs are entered on three pages: Financing, Tax Credit Incentives, and Payment Incentives



SAM 2011.5.4: untitled1

File Case Results Simulations Developer Help

My project x

Select Technology and Market... [ Utility Scale Wind, Independent Power Producer ]

**System Summary**

**Financing**

Analysis: 30 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 1 % per year  
Availability: 100 %

**Wind Resource**

Lat: 41.2 Long: -104.8 Elev: 1868.1 m  
Distance from request: 3.9

**Wind Farm Specifications**

Turbine: V90-2.0  
System Size: 64000.0 kW  
Hub Height: 90 m

**Wind Farm Costs**

**Energy Payment Dispatch**

**User Variables**

**General**

Analysis Period: 30 years  
Inflation Rate: 2.50 %  
Real Discount Rate: 5.50 %  
Nominal Discount Rate: 8.14 %

**Taxes and Insurance**

Federal Tax: 30.00 %/year  
State Tax: 7.00 %/year  
Sales Tax: 0.00 %  
Insurance: 1.00 % of installed cost

**Salvage Value**

Net Salvage Value: 0.00 % of installed cost  
End of Analysis Period Value: \$ 0.00

**Property Tax**

Assessed Percent: 100.00 % of installed cost  
Assessed Value: \$ 124,588,800.00  
Assessed Value Decline: 0.00 %/year  
Property Tax: 1.00 %/year

**Construction Period**

Loan	Percent of Installed Costs	Up-front Fee (%)	Months Prior to Operation	Interest Rate (Annual)	Principal Amount	Interest	Total Cost
Loan 1	0	0	0	0	\$ 0.00	\$ 0.00	
Loan 2	0	0	0	0	\$ 0.00	\$ 0.00	
Loan 3	0	0	0	0	\$ 0.00	\$ 0.00	
Loan 4	0	0	0	0	\$ 0.00	\$ 0.00	
Loan 5	0	0	0	0	\$ 0.00	\$ 0.00	
Totals:	0				\$ 0.00	\$ 0.00	

Note: If you specify construction period loans, the sum of percentages in the Percent of Installed Costs column must equal 100.

**Loan Parameters**

Installed Cost: \$ 124,588,800.00  
Construction Financing Cost: \$ 0.00  
Principal Amount: \$ 49,835,520.00

Loan Term: 20 years  
Loan Rate: 8 %/year  
Debt Fraction: 40 %  
WACC: 11.08 %

**Solution Mode**

# Small Scale vs. Utility Scale Wind



## Resource Data

- Small scale wind uses TMY2, TMY3, or EPW data which has been measured at 10m
- Utility scale wind uses data from the Western Wind and Solar Integration Study data which is modeled at heights up to 200m. The data is based on measurements taken from 2004 to 2006

## Markets

- Small scale wind can be modeled in commercial or residential applications
- Utility scale wind can only be modeled in utility market

## Turbine Libraries

- Small scale turbine library has about 16 turbines ranging in size from 1 to 100 kW
- Utility scale turbine library has about 70 turbines ranging in size from 400 to 3000 kW

# Choosing to model small-scale wind

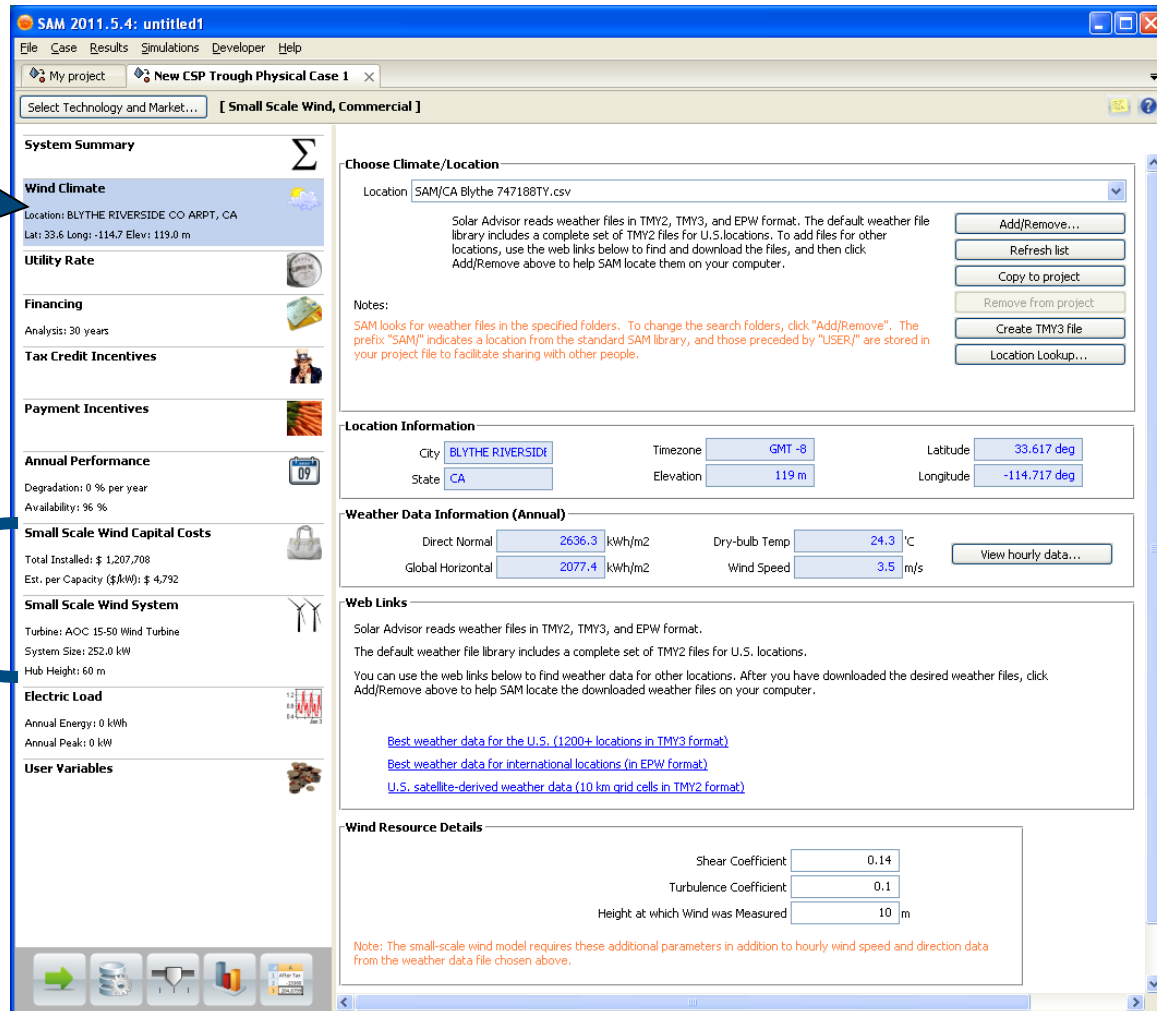


- 1) Click on “Wind”
- 2) Select the “Small Scale Wind” sub-category.
  - With the technology sub-category selected, the appropriate financing categories will appear.
- 3) Click on “Commercial”



# Inputs – Small Scale Wind Resource

Similar to utility scale wind resource page, but no capability to look up data online.



**SAM 2011.5.4: untitled1**

File Case Results Simulations Developer Help

My project New CSP Trough Physical Case 1 x

Select Technology and Market... [ Small Scale Wind, Commercial ]

**System Summary**

**Wind Climate**

Location: BLYTHE RIVERSIDE CO ARPT, CA  
Lat: 33.6 Long: -114.7 Elev: 119.0 m

**Utility Rate**

**Financing**

Analysis: 30 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 0 % per year  
Availability: 96 %

**Small Scale Wind Capital Costs**

Total Installed: \$ 1,207,708  
Est. per Capacity (\$/kW): \$ 4,792

**Small Scale Wind System**

Turbine: AOC 15-50 Wind Turbine  
System Size: 252.0 kW  
Hub Height: 60 m

**Electric Load**

Annual Energy: 0 kWh  
Annual Peak: 0 kW

**User Variables**

**Choose Climate/Location**

Location: SAM/CA Blythe 747188TY.csv

Solar Advisor reads weather files in TMY2, TMY3, and EPW format. The default weather file library includes a complete set of TMY2 files for U.S. locations. To add files for other locations, use the web links below to find and download the files, and then click Add/Remove above to help SAM locate them on your computer.

Notes:  
SAM looks for weather files in the specified folders. To change the search folders, click "Add/Remove". The prefix "SAM/" indicates a location from the standard SAM library, and those preceded by "USER/" are stored in your project file to facilitate sharing with other people.

Buttons: Add/Remove..., Refresh list, Copy to project, Remove from project, Create TMY3 file, Location Lookup...

**Location Information**

City: BLYTHE RIVERSIDE Timezone: GMT -8 Latitude: 33.617 deg  
State: CA Elevation: 119 m Longitude: -114.717 deg

**Weather Data Information (Annual)**

Direct Normal: 2636.3 kWh/m2 Dry-bulb Temp: 24.3 °C  
Global Horizontal: 2077.4 kWh/m2 Wind Speed: 3.5 m/s

View hourly data...

**Web Links**

Solar Advisor reads weather files in TMY2, TMY3, and EPW format. The default weather file library includes a complete set of TMY2 files for U.S. locations. You can use the web links below to find weather data for other locations. After you have downloaded the desired weather files, click Add/Remove above to help SAM locate the downloaded weather files on your computer.

[Best weather data for the U.S. \(1200+ locations in TMY3 format\)](#)  
[Best weather data for international locations \(in EPW format\)](#)  
[U.S. satellite-derived weather data \(10 km grid cells in TMY2 format\)](#)

**Wind Resource Details**

Shear Coefficient: 0.14  
Turbulence Coefficient: 0.1  
Height at which Wind was Measured: 10 m

Note: The small-scale wind model requires these additional parameters in addition to hourly wind speed and direction data from the weather data file chosen above.

Cost page and turbine choice / layout pages are very similar to utility scale wind input pages.

Different turbines are available in the small scale turbine library.



Push F1 for help on each page  
for additional information

**Small Scale Wind System**

File Case Results Simulations Developer Help

My project New CSP Trough Physical Case 1

Select Technology and Market... [ Small Scale Wind, Commercial ]

### System Summary

**Wind Climate**

Location: BLYTHE RIVERSIDE CO ARPT, CA  
Lat: 33.6 Long: -114.7 Elev: 119.0 m

**Utility Rate**

**Financing**

Analyst: 30 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 0 % per year  
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**Small Scale Wind Capital Costs**

Total Installed: \$ 1,207,708  
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**Small Scale Wind System**

Turbine: AOC 15-50 Wind Turbine  
System Size: 252.0 kW  
Hub Height: 60 m

**Electric Load**

Annual Energy: 0 kWh  
Annual Peak: 0 kW

**User Variables**

**OpenEI Online Utility Rate Database**

Search for rates... Go to website...

**Description**

Name  
Description  
Schedule  
Source

**Rate Escalation**

Notes:

- Escalation is applied to all utility rate values.
- Inflation is included with a single value escalation but not for an escalation schedule.
- Escalation schedules are yearly nominal values.

Out-years escalation rate(s) 0 %/yr

**Net Metering**

Note:

Enable net metering (buy=sell) ☒

Net metering applies to Flat Rate and Time of Use Rate sections.

**Fixed Monthly Charges**

Fixed Monthly Charge 0 \$

**Flat Rate**

☒ Enable Flat Rates

Flat Buy Rate 0.12 \$/kWh Flat Sell Rate 0 \$/kWh Flat Fuel Adjustment 0 \$/kWh

**Time of Use Rate (Energy Charge)**

☒ Enable TOU Rates

	Buy \$/kWh	Sell \$/kWh	Adj. \$/kWh	Weekday												Weekend											
				12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Period 1	0	0	0	Jan	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	
Period 2	0	0	0	Feb	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	4	4		
Period 3	0	0	0	Mar	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	4	4		
Period 4	0	0	0	Apr	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	4	4		
Period 5	0	0	0	May	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2		
Period 6	0	0	0	Jun	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2		
Period 7	0	0	0	Jul	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2		
Period 8	0	0	0	Aug	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2		
Period 9	0	0	0	Sep	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2		
	0	0	0	Oct	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2		
	0	0	0	Nov	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	4	4		
	0	0	0	Dec	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	4	4		

**Peak Demand Charges**

☒ Enable Demand Charges

Monthly fixed demand charge (\$/kW,peak)



SAM Wind Analysis

# **RUNNING SAM, OUTPUTS**

# Running the model



Click the green arrow on the bottom left to run the model

SAM displays a progress bar while the model is running

**SAM 2011.5.4: untitled1**

File Case Results Simulations Developer Help

My project New CSP Trough Physical Case 1

Select Technology and Market... [ Utility Scale Wind, Independent Power Producer ] 100 %

**System Summary**

**Financing**

Analysis: 30 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 0 % per year  
Availability: 95 %

**Wind Resource**

Lat: 41.2 Long: -104.8 Elev: 1868.1 m  
Distance from request: 3.9

**Wind Farm Specifications**

Turbine: V90-2.0  
System Size: 64000.0 kW  
Hub Height: 90 m

**Wind Farm Costs**

**Energy Payment Dispatch**

**User Variables**

**Choose Wind Resource Location**

Wind Data File: SAM/cheyenne wy\_2005.swrf  
Data source: <http://scctest/wsis/wwis?lat=41.14&lon=-104.82&year=2005>  
Date created: 2010-10-14 05:42:21

Latitude Requested: 41.14 deg  
Longitude Requested: -104.82 deg  
Latitude: 41.175 deg  
Longitude: -104.825 deg  
Distance from request: 3.9 km  
Elevation: 1868.07 m

Location Lookup...  
Add/Remove...  
Refresh list  
Copy to project  
Remove from project

[Click here to view map of \(R\) requested and \(A\)ctual locations](#)

**Annual Average Data**

Wind speeds at different heights

10 meters	3.93137 m/s
20 meters	5.22065 m/s
50 meters	6.57106 m/s
100 meters	7.66317 m/s ✓

The green checkmark indicates the appropriate data for turbine hub height. If no checkmark is visible, the hub height is not appropriate for this wind data. SAM will use the marked data with the appropriate shear factor

Temperature at 10m: 8.49854 °C

View hourly data...

**Wind Resource Details**

Shear Coefficient: 0.14  
Turbulence Coefficient: 0.1

Run all simulations...

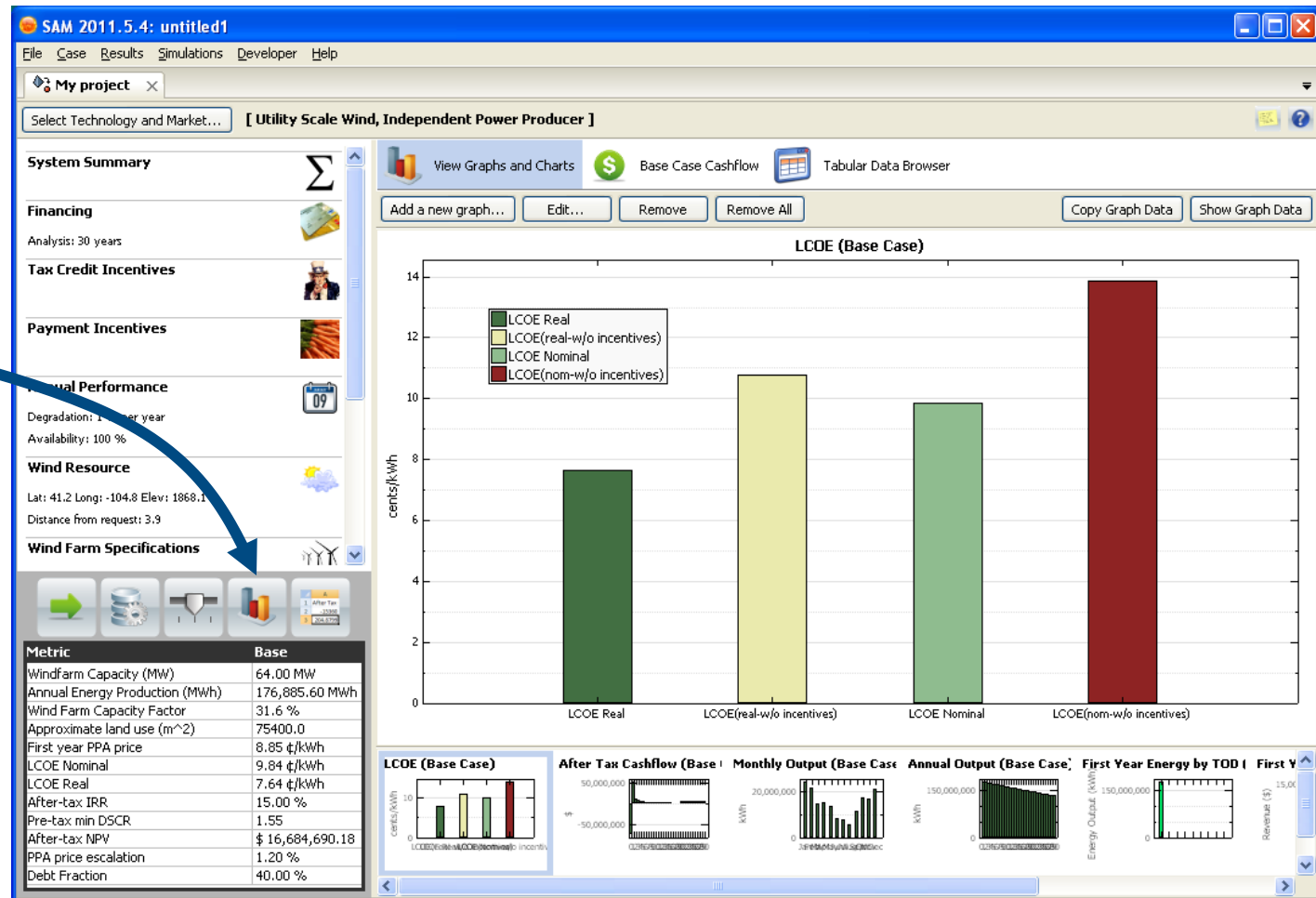
# Default Result Page



When SAM completes the model run, it will default to display graphic results

You can always see the most current set of results by clicking on the "Results" button

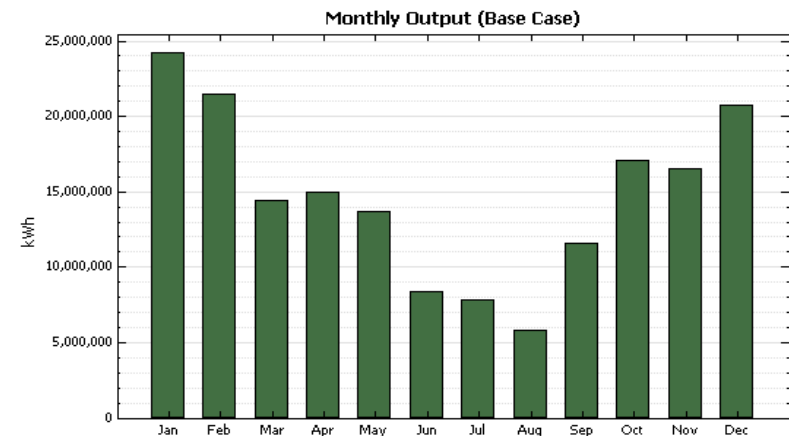
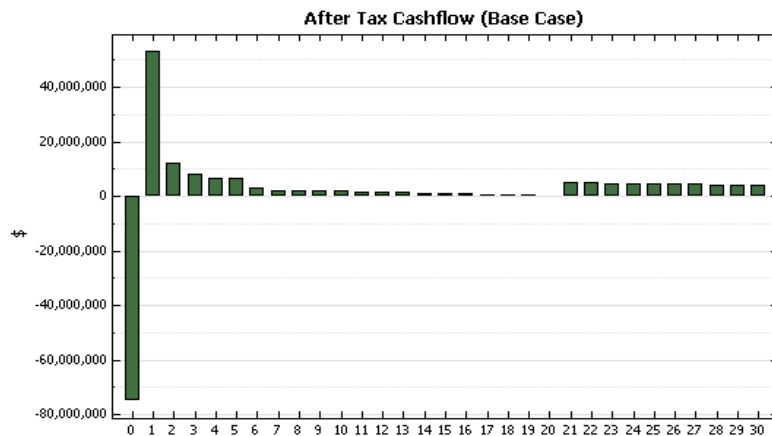
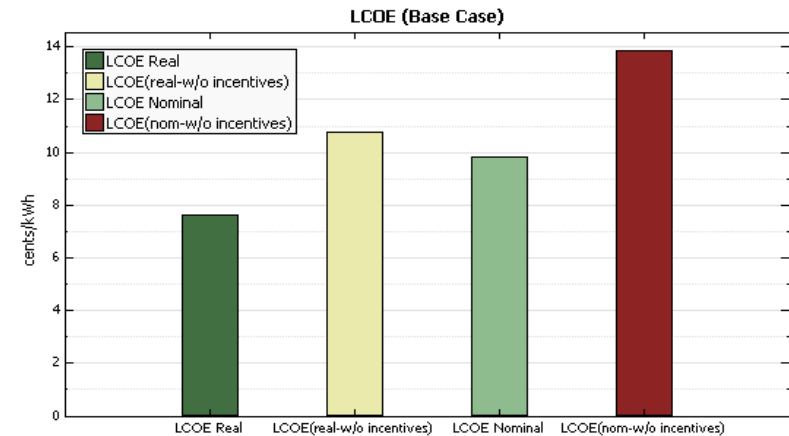
When showing results, SAM displays basic metrics on the bottom left



# Results – Default Graphs



SAM creates several graphs by default, showing financial and energy generation results



# Results – Tabular Cash Flow



Numeric values can easily be viewed and exported

Select  
"Base Case Cashflow"  
or  
"Tabular Data Browser"  
to view numeric data

**SAM 2011.6.23: untitled1**

File Case Results Simulations Reports Developer Help

My project x

Select Technology and Market... [ Utility Scale Wind, Independent Power Producer ]

**System Summary**

**Financing**

Analysis: 40 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 0 % per year  
Availability: 95 %

**Wind Resource**

Lat: 41.2 Long: -104.8 Elev: 1868.1 m  
Distance from request: 3.9

**Wind Farm Specifications**

Turbine: V90-2.0  
System Size: 64000.0 kW  
Hub Height: 90 m

**Base Case Cashflow**

	0	1	2	3	4	5
<b>Energy (kWh)</b>	0	168,041,324	168,041,324	168,041,324	168,041,324	168,041,324
<b>Energy Price (\$/kWh)</b>	0	0.076	0.077	0.078	0.079	0.080
<b>Energy Value (\$)</b>	0	12,798,493.74	12,952,075.66	13,107,500.57	13,264,790.58	13,422,072.00
<b>Operating Expenses</b>						
Recapitalization	0	0	0	0	0	0
Fixed O&M Annual	0	0	0	0	0	0
Fixed O&M	0	3,200,000	3,248,000	3,296,720	3,346,170.8	3,395,841.6
Variable O&M	0	0	0	0	0	0
Fuel O&M	0	0	0	0	0	0
Insurance	0	1,245,888	1,264,576.32	1,283,544.96	1,302,798.14	1,322,307.28
Property Assessed Value	0	124,588,800	124,588,800	124,588,800	124,588,800	124,588,800
Property Taxes	0	1,245,888	1,245,888	1,245,888	1,245,888	1,245,888
Net Salvage Value	0	0	0	0	0	0
<b>Total Operating Expenses</b>	0	5,691,776	5,758,464.32	5,826,152.96	5,894,856.94	5,963,648.88
<b>Operating Income</b>	0	7,106,717.74	7,193,611.34	7,281,347.6	7,369,933.64	7,458,423.12
<b>Financing</b>						
Debt Balance	0	-49,835,520	-48,746,503.81	-47,570,366.33	-46,300,137.84	-44,929,909.35
Debt Interest Payment	0	3,986,841.6	3,899,720.3	3,805,629.31	3,704,011.03	3,599,892.74
Debt Repayment	0	1,089,016.19	1,176,137.49	1,270,228.48	1,371,846.76	1,475,000.00
<b>Debt Total Payment</b>	0	5,075,857.79	5,075,857.79	5,075,857.79	5,075,857.79	5,075,857.79
<b>Federal IBI</b>	0					
<b>State IBI</b>	0					
<b>Utility IBI</b>	0					
<b>Other IBI</b>	0					
<b>Total IBI</b>	0					
<b>Federal CBI</b>	0					
<b>State CBI</b>	0					
<b>Utility CBI</b>	0					

**Metric Base**

WindFarm Capacity (MW)	64.00 MW
Annual Energy Production (MWh)	176,885.60 MWh
Wind Farm Capacity Factor	31.6 %
Approximate land use (m^2)	75400.0
First year PPA price	7.62 \$/kWh
LCOE Nominal	8.64 \$/kWh
LCOE Real	7.26 \$/kWh
After-tax IRR	15.50 %
Pre-tax min DSCR	1.40
After-tax NPV	\$ 22,379,594.88
PPA price escalation	1.20 %
Debt Fraction	40.00 %

# Results – Tabular Data Browser



Numeric values can easily be viewed and exported

**SAM 2011.6.23: untitled1**

File Case Results Simulations Reports Developer Help

My project x

Select Technology and Market... [ Utility Scale Wind, Independent Power Producer ]

**System Summary**  $\Sigma$

**Financing**

Analysis: 40 years

**Tax Credit Incentives**

**Payment Incentives**

**Annual Performance**

Degradation: 0 % per year  
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**Wind Resource**

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**Metric** **Base**

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Pre-tax min DSCR	1.40
After-tax NPV	\$ 22,379,594.88
PPA price escalation	1.20 %
Debt Fraction	40.00 %

**Output Variables**

- Metrics
  - Monthly Data
    - Annual Data
      - Data: 101 values
        - Hourly Data
          - ☒ Hourly Energy (kWh)
          - ☐ Wind Direction (0-360), Hourly
          - ☐ Wind Farm Efficiency (%), Hourly
          - ☒ Wind Velocity (m/s), Hourly

**View Graphs and Charts** **Base Case Cashflow** **Tabular Data Browser**

Choose Simulation: Base Case Copy to clipboard Save as CSV... Send to Excel

**Hourly Energy (kWh) Wind Velocity (m/s), Hourly**

1	0	7.61633
2	17773.7	7.6376
3	21733.6	8.23463
4	30143.8	9.14825
5	29525.2	9.0712
6	28428.3	8.96993
7	29760	9.10568
8	30113.8	9.1251
9	27498.8	8.85062
10	15728.5	7.35578
11	8975.59	6.22656
12	14153.8	7.43427
13	27206.4	9.2222
14	35996.1	10.1919
15	44321.2	11.1502
16	45171.7	11.2214
17	44586.5	11.1089
18	48924.4	11.8292
19	51661.7	15.4973
20	51557.3	20.0877
21	51563.2	21.2344
22	51657.6	18.4789
23	51763	17.8685
24	51968.2	19.8839
25	52276	18.9579
26	52486.4	16.9133
27	52512.3	14.4123
28	51485.3	11.9458
29	51600.4	11.9524
30	51780.2	11.9892
31	51373.1	11.6621
32	52353.8	12.4782
33	51980.2	12.1119
34	50043.8	11.348

Clear all

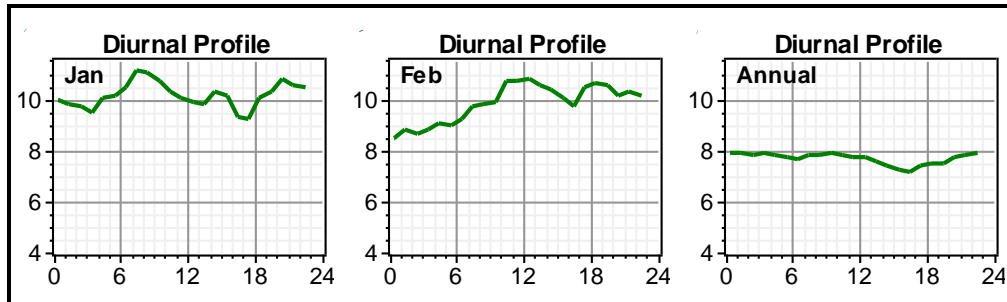
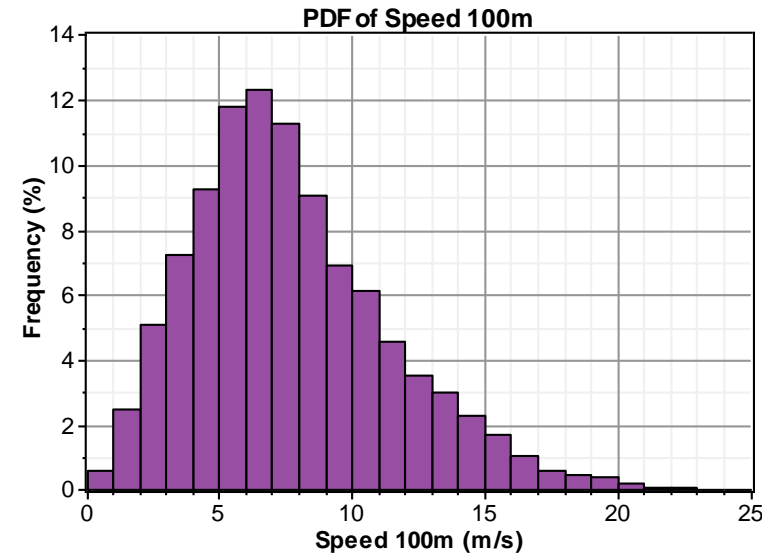
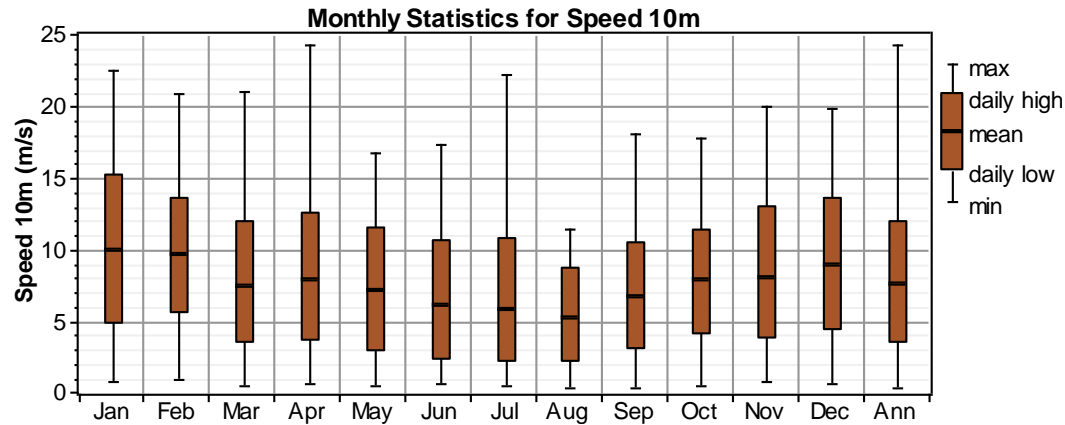


SAM Wind Analysis

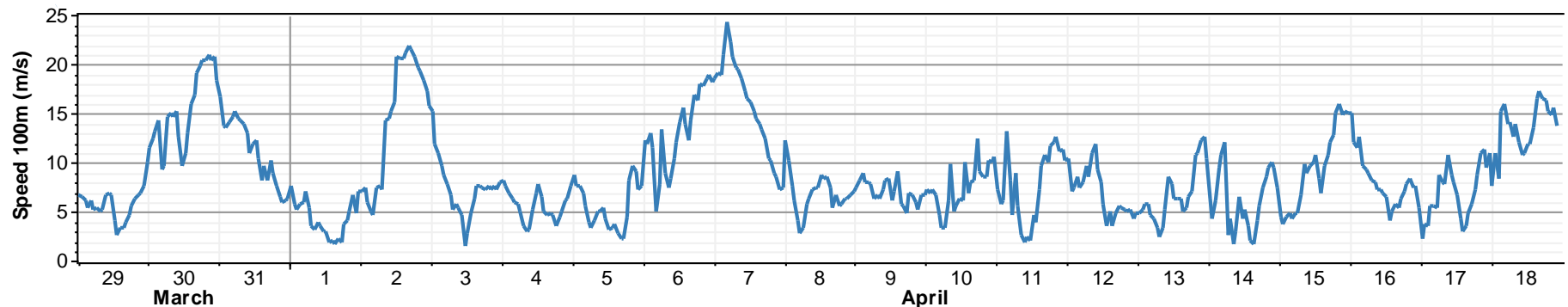
# **ADVANCED TOPICS**



# Advanced Topics - DView



SAM comes with DView, which allows for many advanced views of the wind resource data. DView can be accessed by clicking the "View hourly data..." button on the Wind Resource page

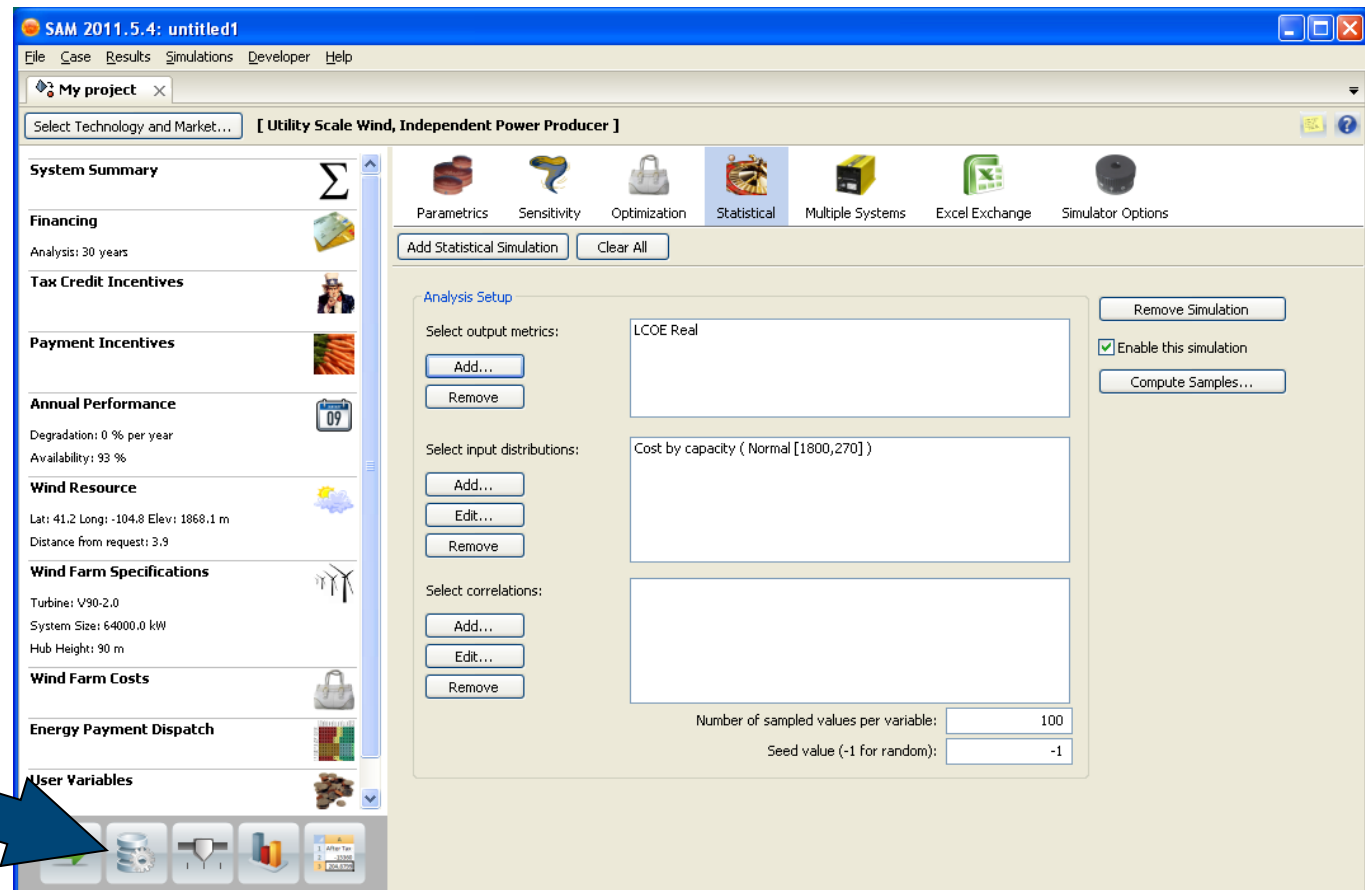


# Advanced Topics – Simulations



Most advanced modeling techniques are accessed through the “Simulations” menu, or the “Configure Simulations” button on the bottom left

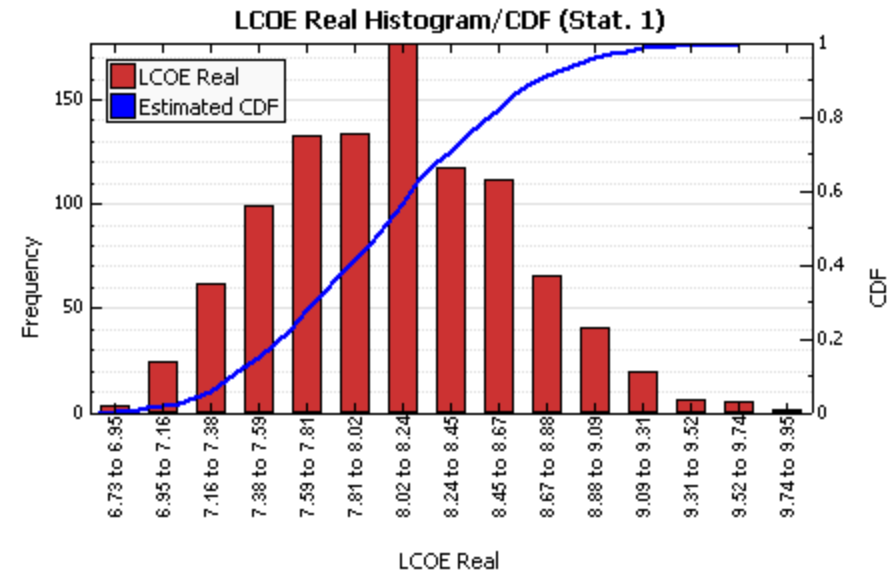
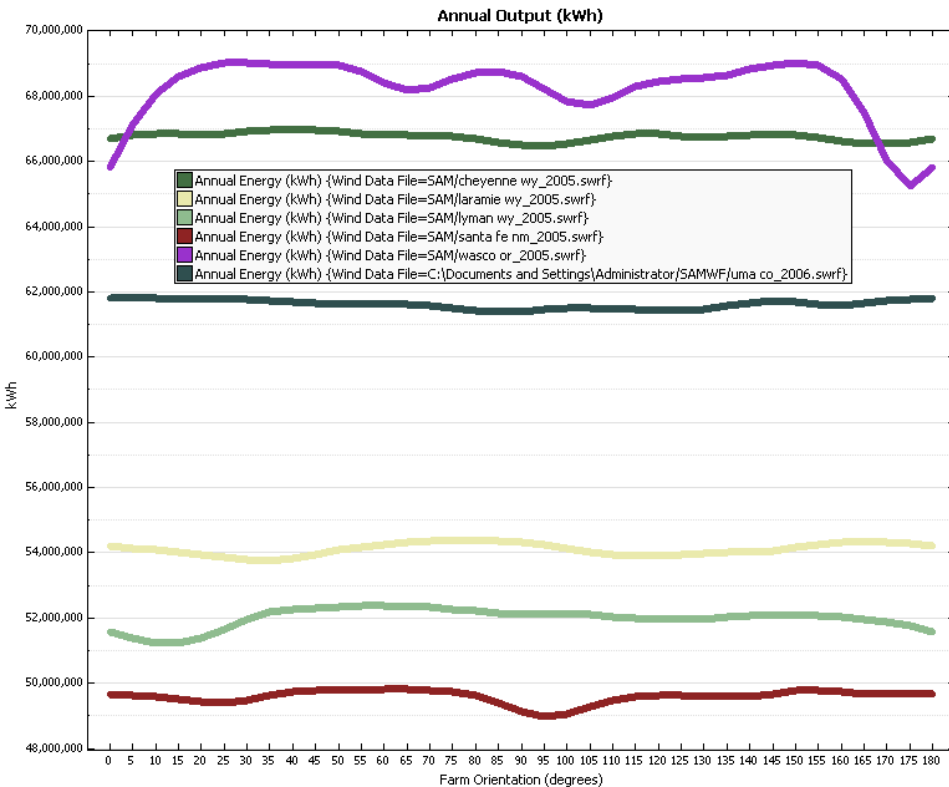
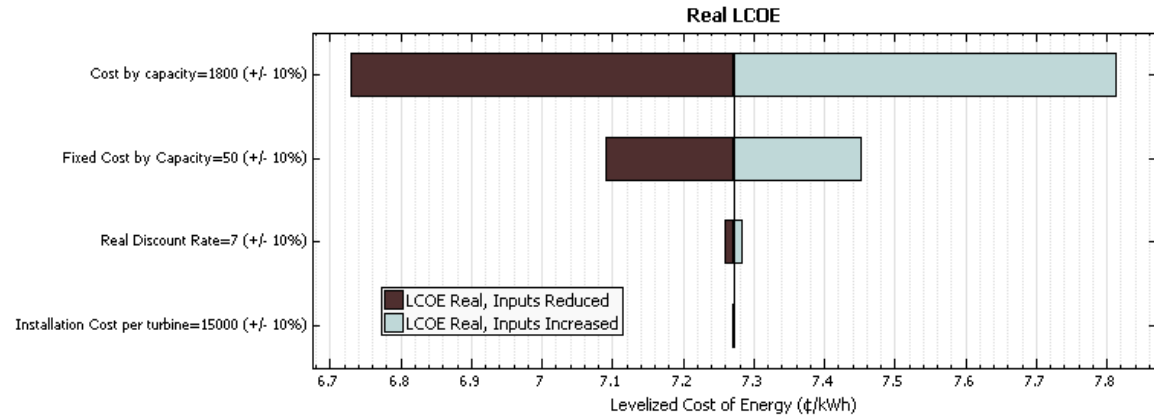
Configure  
Simulations  
button



# Advanced Topics - Uncertainty



## Graphic outputs from uncertainty modeling in SAM



# Advanced Topics - Other



## Excel Exchange

- SAM has the capability to send values to, and receive values from an Excel spreadsheet when running in Windows
- Costs can be calculated externally based on SAM inputs, then the costs can be automatically updated on SAM's cost input page

## Scripting – SAMUL

- A language, similar to VBA, that allows a user to control SAM runs
- Easier than using the full API, since no external development environment is necessary

## API

- SAM has a full featured Application Programming Interface
- SAM will generate example code in C, VBA, Python, and Matlab to show how to run a SAM analysis

See help and sample files for more information

# Thank You!

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SAM Wind Analysis

## DEMO